

**UNCLASSIFIED**

---

**AD 293 099**

---

*Reproduced  
by the*

**ARMED SERVICES TECHNICAL INFORMATION AGENCY  
ARLINGTON HALL STATION  
ARLINGTON 12, VIRGINIA**



---

**UNCLASSIFIED**

NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

CHIIIID

GENERAL DYNAMICS | CONVAIR

Report No. 8926-002

Material - Titanium Alloy - Ti-13V-11Cr-3Al  
(B-120-VCA)

Strength and Driving Characteristics of  
Cold Headed Rivets

Contract AF 33(657)-8926

H. Stier, P. W. Bergstedt, H. C. Turner

24 November 1958

NOV 16 1958

CATALOGED BY ASTIA  
AS AD NO. 293049

Report 8926-002

Material - Titanium Alloy - Ti-13V-11Cr-3Al  
(B120-VCA)

Strength and Driving Characteristics of  
Cold Headed Rivets

Abstract

Three-sixteenths inch diameter cold headed flat-head Ti-13V-11Cr-3Al (B-120-VCA) titanium alloy rivets were fastened into 0.043 inch thick 4130 steel strips heat treated to 180,000 to 200,000 psi ultimate tensile strength. Ultimate shear strengths of 109,000 to 100,000 psi were developed by gun driving and squeezing cold headed rivets and by gun driving cold headed and annealed rivets. Severe cold working during cold heading caused rivet breakage during driving, but this was relieved by vacuum annealing prior to driving.

Reference: Stier, H., Bergstedt, P. W., Turner, H. C.,  
"Cold Headed Rivets of B-120-VCA Titanium Alloy,"  
General Dynamics/Convair Report MP 58-262, San Diego,  
California, 24 November 1958 (reference attached).



**OBJECT:**

To determine the strength and driving characteristics of cold-headed rivets of B-120-VCA titanium alloy.

**CONCLUSION:**

1. Lapped joints fastened by cold-headed B-120-VCA rivets with protruding flat heads have these strengths: (when tested at room temperature in joints in hardened 4130 steel sheet)

	<u>Cold-Headed Rivets</u> Gunned      Squeezed		<u>Cold-Headed &amp; Annealed Rivets</u> Gunned
Ultimate shear, psi - - - - -	109,600	109,400	110,400
Ultimate tensile, psi - - - - -	59,400	62,000	96,000

2. The cold-headed rivets have a severely deformed grain structure at the base of the manufactured head which causes the rivets to fail by snapping off the manufactured head when loaded in shear or tension.
3. The cold work effects (mentioned in 2) can be relieved by an annealing treatment of the cold-headed rivets before driving (vacuum anneal at 1450°F., 30 min., AC).
4. The strength of gunned rivets which have not been vacuum annealed before driving depends upon who's behind the gun as shown below:

	<u>Ultimate shear,</u> <u>psi</u>	<u>Ultimate tensile,</u> <u>psi</u>
G-6 gun, Riveter #1	76,700	15,200
G-6 gun, Riveter #2	109,600	59,400

5. Corrosion in 7075-T6 Alclad is accelerated by the bare B-120-VCA rivets.
6. A load of 11,200 pounds is required to squeeze a 1/4 in. diameter head on a 3/16 in. diameter B-120-VCA rivet.

**TEST SPECIMENS:**

The rivets provided for this test were 3/16 in. diameter flat-head rivets of B-120-VCA titanium which had been cold-headed in the annealed condition. The manufactured heads had a fillet of .008 in. radius between the head and the shank. Rivet shanks protruded 1.14 diameters before driving in the sheet combinations of this test.

TEST SPECIMENS: (Continued)

The shear specimens were of the single lap-joint type with two tandem rivets spaced at  $3/4$  in. along the longitudinal center-line of the joint and with  $1/2$  in. of edge distance. The sheet material was .063 in. thick 4130 steel strips, 2 in. wide, heat treated to 180,000 - 200,000 psi.

The tension specimens were similar to those of Figure 1 of ETL Report 9536 having a single rivet through two sheets of .063-in. thick 4130 steel, heat treated to 180,000 - 200,000 psi.

Two methods of driving of rivets were employed in fabricating the shear and tension specimens:

- a) squeezing with a flat set in a pneumatic compression riveter, and
- b) gunning with a flat set in a G-6 pneumatic rivet gun.

Rivets which cracked during driving were removed from rivet holes with a drill and punch. Driven rivets were inspected for cracked, off center, or tilted heads.

One group of rivets was vacuum-annealed (1450°F., 30 min., AC) after cold-heading and prior to driving. These rivets were sealed in a Vycor glass tube at a pressure of about 3 microns of mercury. The rivets were cleaned with alcohol and absorbent cotton before annealing.

Corrosion specimens had three driven rivets spaced at one inch along the longitudinal center line of .125" x  $1\frac{1}{2}$ " x 10" coupons of clad 7075-T6 sheet or 321 stainless steel sheet.

TEST PROCEDURE:

The shear specimens were pulled in a 60,000 pound Tinius-Olsen tensile machine at a maximum loading rate of 1000 pounds/min. A U-1 extensometer or an S-1 extensometer was used to measure the yield strength of the joint by recording a stress-strain curve from which the load corresponding to a permanent joint set of .005" could be determined. The curve was continuous and was intersected by an off-set drawn parallel to the straight-line portion.

The tension specimens were forced apart with a special fixture (described in ETL Report 9536) which produced a tensile load on the rivet. The fixture was loaded in compression at 1000 or 4000 pounds/min. in the 60,000 pound Tinius-Olsen machine.

The corrosion specimens were wiped with alcohol and placed in a salt spray cabinet for observation. The salt spray was operated in accordance with Federal Test Method Standard 151, Method 811.

RESULTS & DISCUSSION:

The results of Table I show the importance of proper gunning techniques and the beneficial effect of vacuum-annealing of rivets prior to gunning. The low strength of specimens gunned by Riveter #1 can be attributed to his unfamiliarity with the rivet material. Driving of the cold-headed B-12OVCA rivets (no thermal treatment after cold-heading) requires a heavy manual force behind the G-6 gun. Riveter #1 used insufficient force with the G-6 gun and produced a driven head which was widest at the top. Properly gunned rivets have driven heads which bulge at mid-height.

Vacuum annealing of rivets after cold-heading and prior to driving not only improved the strength but also permitted easier gunning of the rivets. No heads cracked or snapped off during gunning of the vacuum-annealed rivets. (Four of the un-annealed manufactured heads snapped off while being gunned.) Most of the driven heads of annealed or un-annealed rivets were somewhat off-center however (not rejectable according to MPS-46.05-D).

The type of failure of the vacuum-annealed rivets which were tested in tension indicated that the cold work effects in the manufactured heads were completely relieved by the annealing treatment. Instead of snapping off when loaded in tension, the manufactured heads sheared along a surface parallel to the surface of the rivet shank. (Also, see ADDENDUM below.)

The load required to squeeze the protruding heads of the 3/16 in. diameter titanium rivets to .250±.007 in. diameter is given in Table II.

The corrosion specimen incorporating titanium rivets in clad 7075-T6 sheet was severely attacked after 250 hours in the salt spray cabinet. A heavy, grey, adherent scale covered the Alclad in areas up to one inch in diameter near each rivet. The corrosion specimen incorporating titanium rivets in type 321 stainless steel was slightly attacked after 400 hours in the salt spray cabinet. A small amount of rust appeared to be emanating from the crevices between the rivet heads and the stainless sheet.

ADDENDUM: Micro-sections through the manufactured heads showed a complete recrystallization of the cold worked grains after vacuum annealing. (See Fig. 1.) The severely deformed grains were replaced by a new set of polygonal grains of approximately the same grain size & hardness as the non-deformed grains. The Rockwell C hardness in the deformed & non-deformed grains is given below:

	Hardness in deformed grains, Rockwell C *	Hardness in non-deformed grains, Rockwell C *
Cold-headed rivets . . . . .	38 - 40	30 - 32
Cold-headed & vacuum annealed rivets . . . . .	30 - 33	30 - 32

\* Rockwell C converted from Knoop indentations with 1400 gram load.

NOTE: The data from which this report was prepared are recorded in Laboratory Data Book No. 3011.

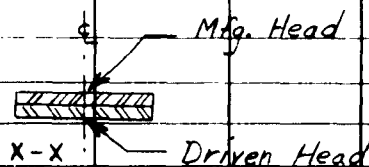
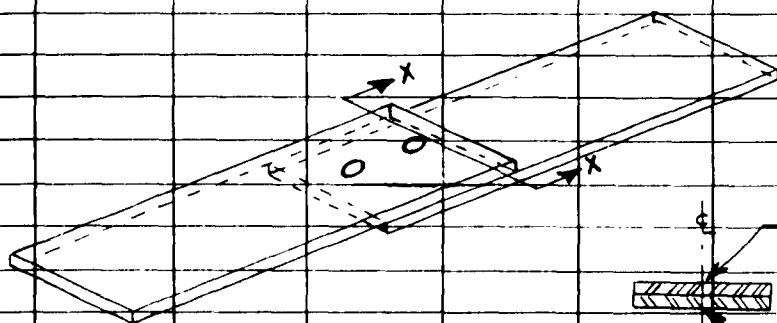


TABLE I. RESULTS OF TESTS OF RIVETED JOINTS INCORPORATING  
PROTRUDING HEAD B-120-VCA TITANIUM ALLOY RIVETS  
IN 4130 STEEL SHEET<sup>(g)</sup>

FORM 73

## SHEAR TESTS OF RIVETED LAP-JOINTS

Identif.	Rivet	Meas'd.	Driven	Thermal	YIELD	ULT.		ULT.	TYPE		Identif.
	Driving	Hole	Head	Treatment	LOAD	LOAD		STRENGTH	OF		
	Method	Diam., In.	Diam., In.	of Rivets	#/rivet	#/rivet		psi. <sup>(d)</sup>	FAILURE <sup>(e)</sup>		
1-1	Squeeze	.192-.194	.252-.254	NONE	2670	3075		105,500	1		X-1
2-2	" <sup>(a)</sup>	.193-.194	.252-.257	"	2895	3155		107,300	1&2		X-2
3-3	"	.193-.194	.248-.253	"	3115	3338		113,500	1		X-3
4-4	"	.191-.191	.254-.256	"	3003	3180		111,200	1		
				Avg.	2921	3187		109,375			
5-5	Gun <sup>(b)</sup>	.193-.193	.228-.248	NONE	--	2578		88,000	1		X-4
6-6	"	.193-.194	.243-.249	"	--	2743		93,300	1		
7-7	"	.191-.193	.242-.246	"	--	1595		55,200	1		
8-8	"	.191-.192	.247-.250	"	--	2023		70,200	1		
				Avg.		2235		76,675			
I	Gun <sup>(c)</sup>	.189-.190	.273-.277	NONE	2995	3155		111,300	2		II
II	"	.188-.189	.251-.264	"	2945	2985		106,400	1&2		III
III	"	.190-.190	.259-.278	"	3000	3295		116,300	2		
IV	"	.188-.188	.267-.274	"	2710	2890		104,200	1&2		
				Avg.	2913	3081		109,550			
N-5	Gun <sup>(c)</sup>	.190-.192	.270-.272	ANNEAL	2745	3045		106,200	2		N-1
N-6	"	.189-.190	.268-.270	" <sup>(f)</sup>	2860	3160		111,500	2		N-2
N-7	"	.189-.190	.268-.285	"	2825	3200		113,400	2		N-3
				Avg.	2810	3135		110,367			N-4



(a) Chicago Pneumatic compression riveter CP-625.

(b) Gunned in Dept. 31 with G-6 pneumatic rivet gun - Riveter # 1.

(c) " " Plant 2 " " " " " " - Riveter # 2.

(d) Based on measured hole diameter.

(e) See FAILURE NOTES at right.

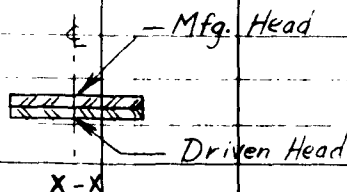
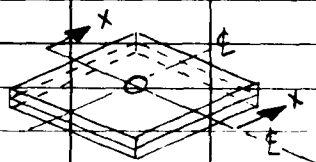
(f) Cold-headed rivets were vacuum annealed before driving (1450°F., 30 min., AC)

(g) Thickness .063"; heat treated to 180,000-200,000 psi. ( $R_c = 41.5-46.8$ ).

FAIL

TENSION TESTS OF RIVETED JOINTS

	Identif.	Rivet	Meas'd.	Driven	Thermal	ULT.		ULT.	TYPE	
		Driving	Hole	Head	Treatment	LOAD		STRENGTH	OF	
a)		Method	Diam., In.	Diam., In.	of rivets	#/rivet		psi. (d)	FAILURE (e)	
	X-1	Squeeze	.199	.243-.258	NONE	1500		48,200	1	
	X-2	" (a)	.192	.241-.253	"	1795		62,100	1&3	
	X-3	"	.193	.248-.257	"	2225		75,600	1&3	
					Avg.	1840		61,967		
	X-4	Gun <sup>(b)</sup>	.192	.248-.257	NONE	440		15,200	1	
	II	Gun <sup>(c)</sup>	.189	.278	NONE	2260		80,600	1	
	III	"	.189	.275	"	1070		38,200	1	
					Avg.	1665		59,400		
	N-1	Gun <sup>(c)</sup>	.190	.277-.286	ANNEAL.	2620		92,400	4	
	N-2	"	.189	.271-.291	" <sup>(f)</sup>	2720		97,000	4&5	
	N-3	"	.190	.260-.267	"	2790		99,000	4&5	
	N-4	"	.190	.271-.283	"	2710		95,700	4	
					Avg.	2710		96,025		



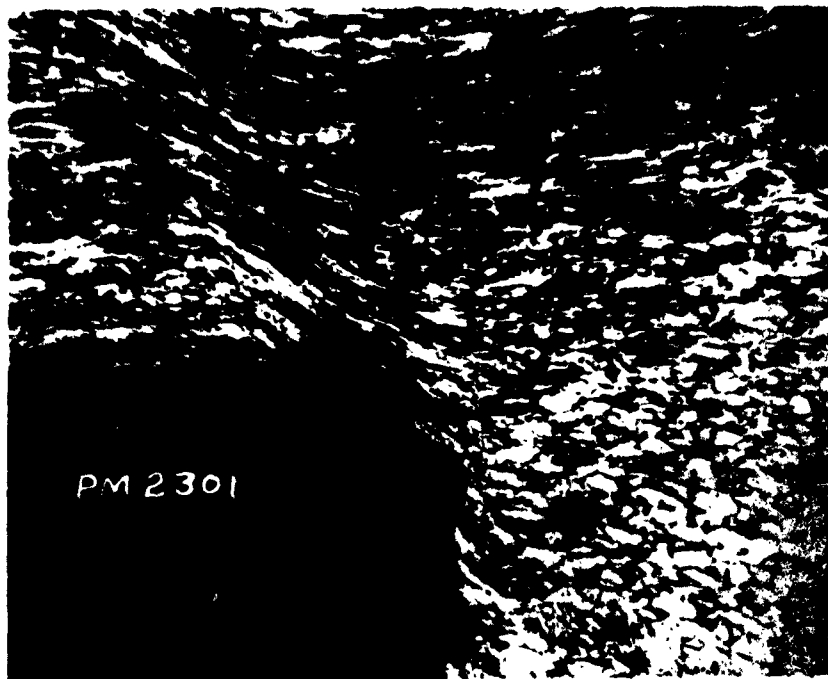
2

FAILURE NOTES:

1. Mfg. heads snapped off.
2. Rivet sheared in the shank along sheet interface.
3. Chipped mfg. head.
4. Shear thru mfg. head parallel to the surface of the rivet shank.
5. Partial tensile failure within mfg. head.

TABLE II,  
RESULTS OF RIVET-DRIVING TESTS OF B-120-VCA TITANIUM RIVETS.

[illegible]



Microsections through the manufactured heads of rivets of B-120-VCA titanium alloy. TOP: Cold-headed. BOTTOM: Cold-headed & vacuum-annealed. (100-X. Kroll's etch.)

FIGURE 1.